2.0 Historical Overview of Activities at the ORGDP

This section contains a chronological overview of principal historical activities at the ORGDP, presented within a series of functional areas, identifying key site conditions, operations, and practices. Also presented are the actual or potential effects of these conditions, operations, and practices on the safety and health of workers and the public, as well as the environment. Sections 2.1 through 2.3 describe the principal historical hazards at the ORGDP; past operational and maintenance activities; practices used to identify, monitor, and control the hazards; and the effectiveness of those practices. Section 2.4 discusses unusual events and accidents. Sections 2.5 through 2.7 describe past practices in worker safety and health, waste management, and air and liquid emission controls and their effectiveness in preventing and mitigating adverse effects on workers, the public, and the environment. Section 2.8 describes historical management and oversight practices and employee relations.

2.1 Background

In 1940, President Roosevelt's Advisory Committee on Uranium recommended that the government fund limited research on isotope separation because scientists theorized that enriched uranium-235 might be used as the fuel source for an atomic bomb. For security reasons, the bomb development program was placed within the control of the U.S. military. The project was assigned to the Army Corps of Engineers because of the major construction effort that would be required to build the numerous research and production facilities. The atomic bomb project was called the Manhattan Project after the Manhattan (New York) Engineer District headquarters of the Corps of Engineers. In late 1942, the Manhattan Project acquired the 59,000 acre Tennessee site, then known as the Clinton Engineer Works and now referred to as the Oak Ridge Reservation, to establish production facilities to supply fuel for the weapon. The M.W. Kellogg Company, involved with the bomb project since January 1942, was awarded the contract for engineering and construction of a full-scale gaseous diffusion plant. In January 1943, Kellogg created a subsidiary called The Kellex Corporation to design and construct the Plant. The Union Carbide and Carbon Corporation, and its subsidiary Carbide and Carbon Chemicals, were selected to operate the gaseous diffusion plant.

Natural uranium consists of two principal isotopes, uranium-235 and uranium-238. Uranium-235 is fissionable and therefore suitable for weapons applications and for fuel for electrical power generation. The gaseous diffusion process involves the pumping of heated uranium hexafluoride (UF_6) gas through a fine porous membrane, or barrier, which preferentially separates the lighter uranium-235 molecules from the heavier uranium-238 molecules. By repeating this process thousands of times through successive barriers, the natural uranium is enriched in the uranium-235 isotope to the desired assay (or percentage) for its end use.

In the spring of 1943, the final selection of the site for the gaseous diffusion plant was determined and the name K-25 was chosen–K for Kellex and 25 as a code name for uranium-235. Ground was broken on the K-25 power plant in June 1943, which would become the world's largest steam electric plant. In September 1943, construction started on the 54 units that would comprise the main process building, named K-25. It was determined that the ORGDP would not produce fully enriched uranium-235 as originally intended, but would provide lower assay enriched feed material for the process using the electromagnetic method of separation (i.e., the calutron) that was being constructed at Y-12. As K-25 was being designed and constructed, another plant for separating uranium isotopes using a liquid thermal diffusion process was built and operated on land adjacent to the ORGDP powerhouse. This facility, consisting of approximately 30 buildings, was identified as the S-50 project or the Fercleve Plant after its operator, a subsidiary of the H.K. Ferguson Company. The S-50 complex was built in approximately three months. The first slightly enriched product (about one percent assay) from S-50 was withdrawn on October 31, 1944.

World War I Era Rock Crusher and Quarry Near Poplar Creek — February 1946

Economic and political conditions in the United States and the world had a significant influence on the attitudes and behavior of workers at the ORGDP. Initial hiring of the Plant workforce occurred during and immediately following World War II; many Plant workers and managers in the first few years of construction and operation were in the U.S. Army "Special Engineering Department." The work at K-25 was viewed as critical to winning World War II and later to protecting the nation's interests during the Cold War. Plant security literature from the war years strongly emphasized the security needed to protect the Plant's secret mission from the enemy. The Plant provided some of the better paying jobs in the area; workers were proud to be accomplishing a mission critical to national defense and being paid well to do so. The investigation team interviewed many workers who spent their entire careers at the ORGDP, spanning 30, 40, or more years–a testament to the workers' loyalty and desire to serve their country.

Pressure to innovate and meet demanding schedules for producing more enriched uranium was a constant element of work at the ORGDP during its first 10 or 15 years of operation. Production work was often arduous. Conditions were hot, noisy, and dirty and required handling hazardous materials. Complicating these conditions were the radiological considerations for the materials being processed and produced at ORGDP. Security concerns affected the communication of the details of some hazards and consequently the Plant workers' awareness of hazards and protective actions. Many elements of the gaseous diffusion technology, processes, and products were classified, and detailed knowledge of materials and conditions were on a strict "need to know" basis. Given these conditions and influences, early Plant workers accepted the need for security, expecting that they would be told what they needed to know, including information that affected their health and safety. Likewise, there were many unknowns about the health and safety aspects of the new technologies being developed and implemented at the ORGDP, and hazards and controls were evolving as scientific knowledge and field experience was gained.

2.2 Operations

In January 1945, the first UF_6 was introduced to the K-25 process building, and on February 25, 1945, the first complete unit in K-25 operated on process gas. Three weeks later, the first product was withdrawn for shipment to Y-12 for further enrichment in the calutron. By August 1945, all 54 units of the K-25 building were in full operation. On September 9, 1945, after one year of operation, the S-50 plant was permanently shut down, its inefficient thermal diffusion process unable to compete with the gaseous diffusion process. The S-50 plant employed as many as 1,600 people and produced almost 13,000 pounds of enriched uranium a month at its peak. However, the plant was burdened with equipment and operational problems that resulted in frequent and large leaks of process gas, amounting to as much as 4,300 pounds of uranium a month unaccounted for or released to the environment. The evolving controls for protection of workers' health and safety were poorly followed and enforced. Workers in the S-50 plant were frequently exposed to hydrogen fluoride (HF) gas and uranyl fluoride (UO_2F_2) powder from UF_6 releases that resulted in frequent burns and respiratory tract injuries.

In mid-1945, with partial feed from S-50, which had ceased feeding Y-12, K-25 was supplying sizeable amounts of feed material (up to 30 percent assay) to the Y-12 beta calutrons; these calutrons produced the weapons-grade (95 percent assay) uranium-235. In an effort to increase production, an additional cascade building, designated K-27, was built at the ORGDP. Building K-27 became operational in January 1946, operating as an extension to the K-25 building. By December 1946, the ORGDP cascade was producing weapons-grade uranium-235 enriched to approximately 93 percent assay, thereby eliminating the need for the high enrichment calutrons at Y-12. In 1948, K-25 and K-27 started operating in series as one long cascade. By September 1950, a third production building, K-29, was built and became fully operational by January 1951. This facility increased total cascade output by about 60 percent. Diffusion capacity grew again in August 1951, when the K-31 building diffusion stages were brought on line, operating between K-27 and K-29 in the cascade. In 1954, K-33, the last cascade building, became operational. Workers in the cascade buildings were occasionally exposed to process gas as a result of accidental leaks during feeding, sampling, withdrawal, and maintenance, and as a result of equipment failures. Records and interviews with former workers indicated that availability and use of respiratory protection by workers directly involved with high-risk activities was generally good, but co-located workers often were not protected.

Concurrent with the construction and initial operation of the K-25 process building(s), significant R&D activity was under way in support of the gaseous diffusion process and other phases of weapons material production. For the gaseous diffusion process to be successful, efficient barrier material had to be developed and manufactured. A Cascade Pilot Plant supported research on barrier technology and conducted barrier efficiency testing for all three gaseous diffusion plants (Oak Ridge, Paducah, and Portsmouth). Building K-1401 also contained barrier development test loops. A barrier manufacturing facility, K-1037, operated from 1947 until 1982. K-633, built in 1950, was a diffusion equipment test facility capable of testing the design and function of full-size diffusion equipment prior to placement in the cascade. Test loops in this facility used cascade UF_6 tails downflow as feed, which was piped back to the cascades at the end of the test loop cycle. The potential for worker exposure in K-633 was high, because numerous components were repeatedly welded into and cut out of the four test loops. Compressor testing facilities were also located in K-1303 and K-1413. Two other R&D facilities performed oxide conversion in the late 1940s. The first fluorination facility at K-25 was the K-1301 oxide conversion building, constructed in 1945. This facility fluorinated uranium oxide, in the form of U_3O_8, into UF_6. This was a very contaminated facility and was closed in 1955 when improved facilities came on line in K-1420. Another oxide conversion laboratory operated in K-1405-6 between 1947 and 1952. This laboratory contained a pilot plant that produced UF_6 by fluorinating UF_4 from tank waste and uranium oxide produced by the Hanford Site's Purex Plant. This was also a very contaminated facility. Forty-nine workers in K-1405-6 had positive uranium bioassay results in the first quarter of 1950. The production of UF_6 in K-1405-6 ended when a newer oxide conversion facility was installed in K-1413. Workers in all of these facilities had the potential for exposures to UF_6 and other hazardous materials. Material release reports from the 1950s indicated periodic accidental releases of UF_6 in these facilities. Airborne nickel dust was a continuous problem in the barrier plant. Records and interviews with former workers indicate that the use of respirators and other personal protective equipment (PPE) was inconsistent.

Aerial View of Site — circa 1968

As a result of increasing demand for UF_6, an alternative to the original supplier, Harshaw Chemical Company, was needed. Between 1947 and 1951 a feed production plant was designed and built in Building K-1131 to convert uranium dioxide (UO_2) and uranium trioxide (UO_3) into UF_6 using the hydrofluorination and fluorination processes. A fluorine generation plant was constructed in K-1131 to support the feed manufacturing process. Starting in 1948, uranium oxide was produced in the Developmental Laboratory in K-1413 from fuel and tank waste supplied by the Hanford Site. The K-1413 pilot plant conducted research on oxide conversion using Hanford Site material into the 1950s. Starting in 1950, feed material from recycled reactor fuel, first from Hanford and later from Savannah River, was processed into UF_6 in K-1131 and fed to the ORGDP cascade. Uranium from recycled reactor fuel, sometimes referred to as reactor returns, and other waste materials received from the Hanford Site, Savannah River Plant, and the Idaho National Engineering Laboratory contained very small quantities of uranium daughters (e.g., thorium-234 and protactinium-234), transuranics (e.g., plutonium-239 and neptunium-237), and fission products (predominantly technetium-99 and some cesium-137, ruthenium, and strontium-90). Transuranics are far more hazardous than uranium, but since they were present only in low concentrations in the reactor returns, the protective measures for uranium provided adequate protection from transuranics. However, uranium daughters, transuranics, and technetium tended to concentrate in certain Plant equipment, such as the ash receivers from the feed production plant (transuranics), purge cascade equipment (technetium), empty UF_6 cylinders, uranium recovery systems (transuranics and technetium), and cascade instrumentation (technetium). Plant management and technical personnel were aware that traces of plutonium-239 were present in the reactor returns, creating exposure concerns in K-1413 and K-1131. Technetium, although apparently recognized as present in the 1950s, did not become a contamination concern until the 1970s, when substantial amounts created problems in the purge cascade and cascade instrumentation.

In 1952, due to design, equipment, and operational problems, the feed production plant was redesigned and modified, significantly increasing output. The feed manufacturing plant operated until October 1961, when the feed plant at the Paducah Gaseous Diffusion Plant and a commercial facility at Metropolis, Illinois, were capable of meeting the demand for feed material. Although most of the feed material produced from reactor returns was shipped to Paducah, a small portion of it was fed directly to the ORGDP cascade. UF_6 from commercial reactor returns was also fed to the ORGDP cascade intermittently into the 1980s. The feed manufacturing plant was an extremely harsh and dirty environment. Operations and maintenance workers were frequently exposed to leaking uranium powders, fluorine, HF, and UF_6. Operational and accidental releases to the environment were also common. Transuranics and fission products from processing recycled reactor returns were concentrated in dust collection systems, the fluorination towers, and the ash receivers. Radiation levels were also higher at these locations. Feed manufacturing plant workers received the highest monitored radiation exposures at the ORGDP. Usage of respiratory protection was inconsistent and not enforced by supervision.

Other gaseous diffusion support facilities were established in 1944, when the K-1004A, B, C, and D laboratories were constructed to conduct chemical analysis and R&D activities. Uranium recovery and oxide conversion technology research was conducted in the K-1004J laboratory (constructed in 1948), and barrier preparation and a cascade pilot plant operated in K-1004L (constructed in 1950). In the late 1940s and early 1950s, research activities in K-1004J included separation of unranium-235 and other isotopes, including plutonium, from Hanford tank waste and from irradiated fuel slugs. In 1948, uranium recovery facilities were established in K-131; these facilities processed accumulated waste solutions and filter cakes from site decontamination processes. A process equipment decontamination and recovery system at K-1303 operated from 1948 to 1954. Converters from most of the 54 K-25 units were decontaminated during this period. In 1954, K-1420 was constructed to provide a new decontamination and recovery facility. In 1960, an enriched oxide conversion facility was also built and operated in K-1420. Oxide conversion in K-1420 ceased in 1962. Workers in these facilities were exposed to uranium compounds and transuranics, as well as many other hazardous chemicals. Many of the laboratories relied on ventilation hoods for controlling contamination and fumes, but some were not adequate. The application and use of PPE continued to be inconsistent. Material release reports from the 1950s and 1960s documented a number of explosions, process gas releases, and worker exposures.

From 1952 to the 1970s, a contaminated nickel smelter operated at K-1037C, which produced tens of thousands of pounds of nickel ingots a month in the 1950s. The operation of this smelter, along with the associated metal chopping and grinding operations, created hazardous dust, fumes, and airborne contamination. Survey reports record that workers in this area did not consistently wear the available respiratory protection.

In 1960, R&D resumed in K-1004J on another promising isotope separation technology, the gas centrifuge. A small-scale process was built and tested in K-1004J and, in 1971, a pilot plant called the Component Test Facility (CTF) was built in K-1210, housing hundreds of centrifuges. Five additional centrifuge research and test facilities were constructed in the 1970s. The CTF operated until about 1978, when construction began on a full-scale gas centrifuge demonstration facility plant in K-1220. However, in 1985, the gas centrifuge project was cancelled.

Between 1971 and 1981, a second major cascade improvement and uprating program was initiated to modify or replace major components such as converters, compressors, motors, valves, and transformers in order to further increase capacity and improve performance. After service in the cascades, the internal surfaces of components had process gas deposits, including uranium, transuranics, and technetium-99, that collected and were trapped in crevices and low-flow portions of the equipment and system. In most cases, equipment was decontaminated prior to maintenance or modification to prevent the spread of contamination and to minimize exposures and the need for controls. Disassembly and decontamination of components removed from the cascades during the extensive and intensive changeout of cascade equipment, as well as routine repairs and replacement of process components, were conducted in many locations on site. The primary buildings for disassembly and decontamination included K-1410 and K-1303 from the late 1940s until the late 1950s, and K-1420 from 1954 to the 1980s. After initial disassembly and decontamination, components were either transported to maintenance areas such as K-1401 or disposed of.

The production of highly enriched uranium-235 for weapons ended at the ORGDP in 1964. Subsequently, the cascades enriched uranium to about five percent assay for use in commercial reactor fuel. The K-25 building cascade was shut down, except for the K-310-3 and K-311.1 purge cascades, which continued to be used by the operating cascades until 1977. The purge cascades were facilities that collected, withdrew, and vented to the atmosphere light gases that accumulated in the upper end of the process cascade and that would eventually block the flow of enriched UF_6 to the withdrawal point. These gases included nitrogen (typically most of the purge gas), oxygen, argon, and HF. A new purge cascade was put into operation in K-402.9 in 1974, eventually replacing the aging and troublesome K-311.1 facility.

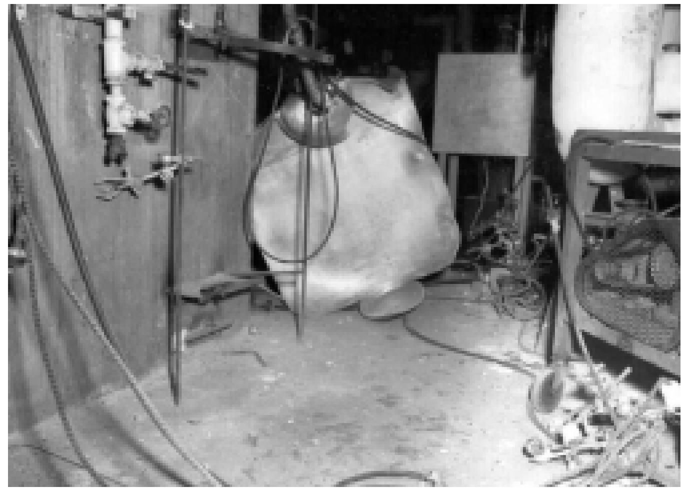
The early 1980s signaled the end of production operations at K-25. In July 1982 the K-1037 barrier plant ceased operating, and all cascade production stopped in August 1985. In 1984, Martin Marietta replaced Union Carbide as the operating contractor at the ORGDP. In December 1987, K-29, K-31, and K-33 were permanently shut down.

2.3 Maintenance

The cascade equipment in the ORGDP complex consisted of thousands of components and millions of feet of piping, barrier tubes, and instrument lines. Many of the components were very large and operated at high speeds and temperatures. From initial startup in 1945 into the early 1980s, some form of upgrading was often in progress. Maintenance was an intensive, continuous activity and, along with process system upgrading activities, was the primary source of radiation exposure, airborne contamination, and many of the releases of UF_6, at the ORGDP. Several major, long-term upgrade campaigns referred to as the Cascade Improvement Program (CIP) and the Cascade Uprating Program (CUP) were performed. A CIP was conducted in 1950 and again between 1971 and 1981, and a CUP was conducted between 1974 and 1981. These programs replaced and upgraded key cascade components, such as converters, compressors, motors, valves, and transformers, to increase diffusion process reliability, capacity, and efficiency. Line management, specifically first-line supervisors, was primarily responsible for specifying and enforcing safety and health controls for workers performing maintenance and modification activities. Industrial hygiene and health physics personnel performed some surveys and monitored work areas routinely, as well as for special situations and when requested by workers or supervisors. Industrial hygiene and health physics also performed annual audits of line health and safety programs from the 1950s to the 1970s. Recommendations for controls, including decontamination and PPE, were provided by industrial hygiene/health physics. These recommendations were inconsistently implemented by line management, supervisors, and workers.

Work on Plant systems and components often required opening of piping and components. On occasion, despite efforts to evacuate and purge UF_6 from the components to be opened, they contained residual UF_6, deposited uranium compounds, transuranics, fission products such as technetium-99, and chemical hazards such as fluorine and HF. Many components had to be removed from the cascade buildings and taken to shops for decontamination, repair, or replacement. Maintenance personnel and chemical operators performing decontamination work were regularly exposed to many hazardous materials, including UF_6, HF, and ClF_3; TCE and other solvents; acids and bases; PCB-contaminated oils; phosgene; transuranics and fission products; and mercury. Work techniques, engineering controls, procedural requirements for PPE use, and the quality and availability of PPE improved through the years. However, Plant records and interviews with former workers and managers indicate that compliance was a recurring problem and enforcement was relatively weak.

Instrument technicians and other workers were exposed to mercury, UF_6, HF, carbon tetrachloride, TCE, technetium-99 (first recognized in the 1970s), and other hazardous materials when performing cleanout, decontamination, calibration, and replacement of process line instruments and chemical traps associated with line recorders. Mercury was present in countless Plant instruments and components and in large volumes received from Y-12 and the Oak Ridge National Laboratory (ORNL). In 1946, mercury recovery processes were in operation in K-1401 and additional distillation operations were conducted in K-1303 from 1948 to 1956, when these operations were transferred to facilities in K-1420. Processing and recovering tons of mercury continued in K-1420 until 1980.



K-1401 UF_6 Cylinder Explosion — September 1953

2.4 Unusual Events and Accidents

There have been numerous serious accidents and events, resulting in exposures, injuries, and deaths of workers, during construction and operation of the ORGDP. In addition, frequent smaller releases and events that also posed health and safety risks and damage to the environment occurred due to the nature of the equipment, the presence of toxic and caustic materials, the physical conditions required for many operations, and management policies and performance inadequacies. Historical records reflect a number of fatalities at the ORGDP in the early years, including auto accidents, falls during construction, lightning strikes (at least three deaths), electrocution, heat stroke (at least three deaths), and several crushing accidents involving heavy equipment and trains. For example, in 1958, two workers died after entering an oxygen-deficient atmosphere in the vapor degreaser tank in K-1420. After major construction activities slowed in the late 1950s, worker fatalities and serious injuries diminished significantly. However, medical records, release reports, and accident investigations indicate numerous heat and chemical burns, rashes, respiratory and nasal irritation, and other injury cases through the 1970s due to accidents associated with toxic or caustic materials. Historical accident/injury frequency and significance data reflect that although the rates compared favorably with other chemical and industrial operations and were lower than the Union Carbide corporate-wide rates, they were higher than those of the other two gaseous diffusion plants (Portsmouth and Paducah). Numerous large fires were reported during the 1940s and 1950s, typically resulting from welding and cutting activities or careless cigarette disposal; injuries due to fire were few.

Accidental spills and releases of acids, solvents, fluorine, and especially UF_6 were the most frequent events that resulted in exposures to workers and contamination of the environment. A number of recent studies have attempted to quantify the releases of uranium, transuranics, fission products, and non-radioactive hazardous materials to the environment, with differing results. Accurately identifying and quantifying all of the releases that occurred is very difficult because of the lack of records, the different methods used to document releases, and changes in reporting-threshold policies. Record reviews and interviews with former workers indicate that many releases were probably not formally documented. Data on accidental releases was especially limited for the 1960s and 1970s. Quantitative data on releases from the S-50 thermal diffusion process is unavailable, but documentation and interviews indicate that accidental releases to the environment in 1944 and 1945 were frequent and often very large. In addition, release records for 1946 through 1950 did not indicate quantities lost, and many reports contained only estimates. Notwithstanding these limitations, the EH investigation team still identified well over 600 releases of UF_6, with 17 in excess of 100 pounds and more than 100 exceeding 10 pounds. Significant releases occurred during cascade feed and withdrawal operations in 1952 (2,500 and 670 pounds), in 1953 (1,628; 592; and 450 pounds), and in 1960 (405; 473; and 1,012 pounds). It is difficult to fully characterize many of these releases because materials may have been fully or partially retained within structures.

Many conditions affect the spread of contamination to the environment and exposure to personnel away from the release point, including the release location, openings in the buildings, ventilation, speed of response by workers, weather conditions, and quantity and assay of material released. UF_6 gas is hydrolyzed with moisture in the air to form HF gas and solid UO_2F_2. HF gas is caustic, and exposure can result in burns to exposed skin and to the respiratory tract. Both HF and UO_2F_2 are environmental contaminants. HF primarily reacts with vegetation and soil, and UO_2F_2, being highly soluble, washes into low points on the ground and into waterways. Typically, materials spilled outside of buildings, including UO_2F_2, were washed down into Plant storm drains by the fire department where the materials flowed to site waterways and eventually to Poplar Creek.

Accidental releases of UF_6 occurred at many locations, including the S-50 project facilities; the cascade feed vaporization, sample, and withdrawal stations; the feed manufacturing plant between 1952 and 1965; the toll enrichment facility; and the R&D and laboratory facilities. Releases also occurred in many parts of the cascades during CIP/CUP activities in the 1970s and during uranium recovery, equipment disassembly, and decontamination activities in K-131/132, K-1303, K-1401, K-1405, K-1410, and K-1420 from the 1940s until the 1980s. Starting in the 1950s and into the mid-1960s, losses of uranium materials, including small puffs, were required to be reported on material release forms, including estimated amounts, circumstances of the event, potential exposures, actions taken, contamination levels, and decontamination efforts. In most cases, proposed or implemented actions to prevent recurrence were identified, and in some cases, more detailed analyses of events and corrective actions were documented in reports and investigations. However, accidental releases continued to occur, often as a result of workers failing to follow procedures or inexperienced or inadequately trained workers. Release records from the 1950s and 1960s generally reported that persons working directly at the release site were wearing respirators or masks, but personnel in the area or responding to the event were often not wearing appropriate PPE. Few records reflect direct involvement by the Atomic Energy Commission (AEC) in formal investigations of serious events.

In general, release reports and other records indicate that the Plant was fairly aggressive in identifying potentially exposed individuals and ensuring that those personnel provided urine samples for analysis and were examined by the medical staff. For example, after an August 23, 1974, UF_6 release from the top product withdrawal station, 28 workers submitted urine samples, 11 of which were over the Plant recall limit for alpha radiation. Recall limits were thresholds where followup urine screenings were performed until uranium excretion levels declined below those limits. If another, higher threshold limit was exceeded, workers were restricted from work where additional exposure was likely until uranium excretion levels fell below the established limit. Sixty-six persons were evaluated following a release from K-413 and K-29 that resulted in a large, visible cloud outside the building and required building evacuations and relocation of evacuees due to shifting winds. Only one person involved in this event was found to be above Plant recall limits. Records indicate that numerous workers were exposed to airborne uranium above Plant limits, many of whom were placed on work restriction and had to submit repeated urine samples for analysis before uranium excretion levels declined below allowable limits. With improvements in equipment and operational techniques for connecting, disconnecting, heating, and sampling UF_6 and for performing maintenance, the number and quantity of accidental releases declined. The cessation of feed manufacturing in 1965 and the end of CIP/CUP work in 1981 also contributed to a decline in accidental releases.

Large quantities of fluorine and HF gas were used at the ORGDP. Fluorine was produced on site, and anhydrous HF was brought to the site and stored in train tank cars or fixed tanks. Significant and frequent releases of these gases occurred, exposing individuals and causing damage to automobiles, building windows, and flora in the area. Worker exposures to these gases resulted in burns and respiratory problems. Available records indicated that many persons were treated for burns from exposure to HF, primarily during the operation of fluorination towers in K-1131, K-1301, K-1405-6, and K-1413. In July 1955, nine workers were burned when a 200-pound HF cylinder exploded. An HF exposure received by a maintenance mechanic in 1959 at the K-1131 fluorine generating plant resulted in skin grafts on the mechanic's neck, face, hand, and arm. This worker, who had suffered previous burns ten times during his employment at the ORGDP, was not wearing the specified PPE, as was also the case for some of his previous burns. Many other spills of various hazardous materials have impacted the environment. Spills of acids, antifreeze, gasoline, sodium hydroxide, chlorine, TCE, greases, chromates, PCB-contaminated oils, and other chemicals have affected vegetation and fish, and have contaminated waterways both on and off site. Release reports from the 1950s reflected a number of spills of quantities of nitric and hydrochloric acids, in one case 200 gallons. Section 4 of this report further discusses the effects of releases on the environment and the monitoring programs for accidental releases.

Accidental releases were frequent, sometimes significant, and more likely to result in acute health impacts on workers than the uranium and fluorine that were continuously released to the environment incidental to normal operations through building and process vents. Conservative estimates from the July 1999 ChemRisk® dose reconstruction report indicated that more than 35,000 pounds of uranium were released to the air from all sources at the ORGDP from 1944 through 1995. These estimated releases ranged from 6,600 and 5,940 pounds in 1945 and 1958, respectively, to less than one-half pound in 1986. Also, accidents caused significantly less harm to the environment than the early standard waste disposal practices did; these included direct discharge of radioactive materials, toxics, and caustics to holding ponds and storm drains, and incineration and burial.

2.5 Worker Safety and Health Programs

Hazard identification and communication were a concern to Carbide and Carbon Chemical Company during Plant construction, because there were many unknowns about the safety and health effects of the materials to be used at the ORGDP. Records reflect recognition that these unknowns needed study and indicate the involvement of safety and health professionals in addressing those concerns. The area of criticality safety, initially referred to as "special hazards," was assigned a high priority. New and modified facilities received thorough criticality safety reviews prior to startup. Standards for safe quantities, configurations, and processes were established and personnel were trained in the handling of enriched uranium. Starting in the 1940s, hazardous and electrical work permits were used at the Plant as safety hazard identification and control mechanisms, evolving into a better defined safety work permit system in 1981. Management also intended that Plant procedures would address work hazards, but assessment data and interviews with former workers indicate that in practice,


Radiation Monitoring Training — July 1959

formal procedures were rarely used or referenced. Starting in the 1960s and continuing into the 1990s, formal job safety analyses (JSAs) were also developed to address health and safety issues for hundreds of different work activities. Records indicate that some formal safety training was available during Plant startup. Safety and health issues were also communicated in a variety of other ways, including safety meetings (held throughout the history of the Plant), distribution of a variety of safety bulletins, and a Safety Practices Manual issued in 1947. A central safety committee, established in 1947, offered interdepartmental communication and provided another vehicle for workers to express safety and health concerns. Formal ES&H training for much of the Plant's operating life was directed at supervisors, who were then tasked to pass necessary information to workers through the safety meetings and on-the-job training (OJT). The 1950s saw publication of a handbook on criticality safety, information on PPE and the treatment of chemical burns, and refresher training on radiation protection for workers and supervisors. Little documentation was located regarding training during the 1960s. The 1970s and 1980s saw a continuation of a program of formal general orientation training followed by informal OJT for hourly workers from supervisors and more experienced workers. Training in the 1990s became much more structured, with formal ES&H training for all Plant employees.

Worker safety and health programs at the ORGDP were generally administered by persons or groups in four functional areas: industrial safety, industrial hygiene, health physics, and medical. Although there were many reorganizations and changes in staffing and structure, these functions reported to the medical director within the industrial relations division from 1946 to 1967. Staffing for these functional groups was minimal until the 1980s, especially for industrial hygiene. Evidence indicates that in the 1940s the health physics staff was active in evaluating the radiation safety aspects of Plant and equipment design and worker protection. Starting around 1950, formal Union Carbide policy at K-25 required that hazard identification, monitoring, and safety and health protection were primarily a line responsibility, with safety and health professionals serving primarily as an advisory body to management and production.

The safety and health organizations provided general hazard awareness information, performed limited radiation and contamination surveys, collected and analyzed air samples, worked with the medical staff to manage the urinalysis and in-vivo bioassay programs, and maintained exposure and contamination records. These organizations also performed periodic, typically annual, program reviews and spot audits of field conditions and performance. Starting in 1945, site industrial hygienists monitored many chemical contaminants. However, the level of oversight provided by the limited staff in these organizations was minimal, especially considering the variety and complexity of work activities at the Plant. Records and interviews indicated that the rigor of monitoring and controls on contamination and worker exposure declined substantially during several decades of limited health and safety oversight. Starting in the mid-1970s, the safety and health organizations achieved more responsibilities, autonomy, and authority, and staffing was increased. Much of this change resulted from issuance of Occupational Safety and Health Administration (OSHA) regulations in the 1970s and 1980s and the increased attention given to ES&H by DOE in the 1980s and 1990s.

Workers likely or suspected of being exposed to radioactive materials were monitored using film badges (thermoluminescent dosimeters, or TLDs, after the mid-1970s) for external exposures and urinalysis and in-vivo (from the mid-1960s to 1990) bioassay programs for inhalation exposures. Although there were limitations in both of these monitoring methods, their use, especially in combination, identified and quantified exposures and minimized additional exposures to workers. Throughout the 1970s, many hundreds of urinalyses were performed each month, often with dozens of workers identified as having exposures exceeding the Plant control guides. Available records reflect that in-vivo testing identified a number of workers with lung burdens significantly above Plant allowable limits (PALs), and calculated internal exposures of between 5 and 15 rem. The number of exposed workers and exposures exceeding PALs declined over the years as better operational practices and protective measures were implemented.

Since Plant startup, airborne radioactive contamination was monitored by continuous and intermittent samplers in many production and non-production areas. Records from the 1940s through the 1960s indicate many air samples in excess of PALs, often related to process upsets, releases, or decontamination and maintenance activities. It is not clear whether monitoring results were consistently translated into better management of contamination or better protection of workers, since there were continual weaknesses in the respiratory protection program. Various masks and respirators were used over the years to prevent inhalation of contaminants. However, it was not until 1973 that a respirator fit-testing program was established. Likewise, contamination surveys and health physics audit reports continually identified poor contamination control in the 1940s and 1950s. Records of AEC and Energy Research and Development Administration (ERDA) assessments in the 1960s and 1970s identified workers not wearing respirators while working on contaminated equipment. Extensive contamination was prevalent in many production areas, and the specification, use, supervision, and enforcement of respiratory protection and personnel monitoring were inconsistent.

In 1943, project management established a comprehensive medical program to care for the thousands of civilian and military workers who would build and operate the ORGDP. The medical program in 1945 consisted of an extensive staff and facilities operating 24 hours a day, supporting surgical procedures and lengthy stays for recuperating workers. Pre-employment, periodic, and termination health examinations were provided for ORGDP workers. In the same year, the military established a full-service hospital in the town of Oak Ridge to support the rapidly growing local community. The medical department was active in evaluating, treating, and monitoring worker exposures to radiological, chemical, and other hazardous material. The industrial hygiene staff reported to the medical director from 1949 to 1980, and the safety and health physics organizations also reported to the medical director intermittently from 1950 to 1967. Medical staffing declined with reductions in Plant population, budget reductions, and reductions in patient needs due to less construction work and better operational controls. By 1961, the medical staff had been cut significantly. In 1972, an AEC headquarters review found the ORGDP medical department understaffed, with outdated facilities and equipment and weaknesses in examination and treatment policies. Corrective actions were taken, but program weaknesses and a lack of resources persisted. The 1991 Tiger Team assessment identified weaknesses in the medical program, including staffing, facilities, and the ability to protect medical records.

2.6 Waste Management

The ORGDP has generated large quantities of radioactive, hazardous, and non-hazardous waste materials that have required storage, treatment, or disposal. These materials included construction debris, demolition waste from former worker housing camps, general office and kitchen trash, classified equipment, highly toxic chemicals, contaminated tools and clothing, scrap metals, and various radioactive substances. External regulation, treatment, and disposal methods and the overall waste management programs evolved over time in response to changing regulations, which resulted in more rigorous requirements for the handling of solid, hazardous, and radioactive wastes. Until the 1960s, there were limited Federal and state restrictions on discharge and disposal activities. Past disposal practices at the ORGDP resulted in significant degradation to the environment that in turn led to the ORGDP being listed in 1989 as part of the Oak Ridge Reservation Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Site on EPA's National Priority List. Consequently, in 1991, DOE entered into a legally binding Federal Facility Agreement with the EPA and the State of Tennessee to remediate the entire Oak Ridge Reservation.

Throughout the Plant's operating history, various disposal sites and methods were used, including sanitary, classified, and radioactive landfills; waste treatment pits and basins; oil degradation plots; incinerators; and unauthorized disposal. During Plant construction and early operations, waste management involved disposal of trash and construction debris. Available sites at the Plant were used for these uncontrolled disposal activities. As production began, low-level radioactive disposal (burial) sites were created and used until the 1970s, when these wastes began going to Y-12 for disposal in radioactive burial facilities. Following construction of a compaction/transfer station in 1968, the sanitary waste that had been going to available Plant locations was sent to the Y-12 sanitary landfill. In addition to burial, the Plant used open burning at several locations for disposing of flammable liquids and materials from the 1940s until the 1960s.

The Plant also had a need for disposal of classified material beginning in the 1950s, leading to the construction of a series of classified landfills that were used through 1985.

As regulations increased in the 1970s, tighter controls on contaminated liquid disposal via pits and ponds resulted in their eventual elimination, and numerous mixed hazardous wastes streams were containerized and placed in storage. These waste streams are currently being characterized and sent to offsite disposal, and most of the formerly utilized disposal sites have been closed in accordance with Resource Conservation and Recovery Act (RCRA) requirements or are awaiting remediation under CERCLA. During this investigation, additional sites were discovered that might have been used for waste treatment and disposal. These sites may require additional screening for consideration as part of the ongoing remedial investigation.

Initially, multiple contractors performed handling and control of waste disposal, including the prime contractor, Union Carbide, and construction contractors, such as JA Jones and Ford, Bacon, and Davis. In 1971, management established a separate organization to manage site wastes and disposal operations. Before 1971, several divisions addressed radioactive waste issues, including cascade services, the design and development department, and uranium control and inspection. By 1957, the safety, fire and radiation control department was responsible for recommending the PALs for disposal of radioactive wastes. In the 1970s, the safety and environmental control division was established, and in the1980s, this division became the environmental protection division. In 1989, the waste management function was established within the DOE organization as a separate division to provide direct technical and management support to the line organizations. In the contractor's organization, the waste management function became a separate division in 1991.

Incineration of radioactive waste materials, which began soon after initial Plant operations, was used as a means to recover uranium from contaminated combustible materials. The first documented incinerator was constructed in 1947 and operated until at least 1951. This incinerator was a likely source of significant radiological contamination within the facility. It processed wastes contaminated with uranium and transuranics from the cascade and feed production operations. There were three generations of incinerators installed in K-1421 from 1955 until the last unit was shut down due to performance problems in 1985. These units burned both contaminated solids and waste oils from the site, including contaminated enriched-uranium items from the cascades and decontamination process materials from K-1420. These units had few automated controls, and the likelihood of incomplete combustion was consistent with observations that the stack often released thick black smoke.

In 1985, incineration of wastes at ORGDP became a broader mission with the termination of uranium enrichment operations. The effort to construct the K-1435 TSCA incinerator began in the mid-1980s to treat both ORGDP legacy wastes and those from other DOE sites contaminated with PCBs. This unit began incinerating mixed wastes in 1991.

Large volumes of scrap and surplus materials having intrinsic value were generated at ORGDP during construction, maintenance, uranium recovery, repairs, and facility upgrades. Very large quantities of scrap and surplus metal from cascade improvement activities in the 1970s and barrier production processes presented unique challenges. Because these materials were considered valuable commodities, there was a desire to maximize recycling for continued Plant use or to salvage for sale to the public. A 1947 AEC directive established a policy of very strict controls associated with scrap and surplus materials with residual contamination prior to their release offsite. This policy was relaxed from the mid-1950s through the 1970s. During this time, large volumes of scrap metal were cast into ingots for public sale. Records indicate that hundreds of thousands of pounds of metal ingots were commercially sold with uranium concentrations of up to 2,500 ppm dispersed through the metal matrix. There were also release limits for surface contamination; however, records indicate that monitoring methods were inconsistent. While contamination limits changed over the years, scrap materials were always required to be segregated by contamination status. Public property sales were held routinely for disposition of materials classified as clean scrap and equipment. Collectively, the large amount of scrap and surplus material generated, the small number of qualified health physicists, and evidence of inconsistent implementation of required radiological surveys make it likely that material exceeding release criteria was sold to the public from the 1940s through the 1980s.

2.7 Air and Water Emissions

Since initial production operations began in 1944, routine, accidental, fugitive, diffuse, and planned emissions of radioactive materials and fluorine have been released to the environment. Accidental releases accounted for about 50 percent of all recorded Plant releases. A fluorine production plant in K-1301, built in the 1940s, suffered numerous equipment failures that resulted in fluorine releases. Subsequent modifications to rupture disks on fluorine storage tanks reduced the frequency of these releases. Ambient air sampling for fluorine and HF did not begin until 1959. The limited measurements of UF_6 releases to the atmosphere were also insufficient to accurately characterize radionuclide releases in the early years. The installation of a bubbler sampler in 1971 on the purge cascade improved the accuracy of stack release estimates.

Radionuclide emissions consisted principally of uranium and its daughter products, and technetium-99. The total historical uranium release for ORGDP was estimated at 16,000 kg. This value is likely underestimated based on the results of this investigation. As an example, the feed plant started operations in 1952, but the first emission measurements were not recorded there until 1954. The 1999 ChemRisk® dose reconstruction study did not include a significant number of releases and underestimated some airborne releases to the environment. For example, release estimates from the reconstruction did not include data from 1945 to 1949, but historical records indicated several large releases during this time. Additionally, the dose reconstruction study estimated total discharges of 3,000 kg of uranium for the 12 months of operation of the S-50 thermal diffusion facility. However, operating data for this Plant indicate that reported atmospheric losses were approximately 2,200 kg in only five months of operation, with an additional 9,000 kg of uranium unaccounted for during these five months. The accuracy of past release estimates is problematic, given the inherent uncertainties in these measurements combined with the fact that no soil deposition patterns were investigated. It is estimated that an average of

East Side of Process Building — July 1945

approximately 2.5 curies per year of technetium-99 were released at the ORGDP during its operating life.

Liquid effluents containing both chemical and radiological materials have routinely been discharged from the Plant. Historically, these have occurred from both sanitary sewage and storm water systems in addition to discharges from the K-1407B and K-1407C retention basins. There are documented instances where materials were directly discharged into Mitchell Branch and Poplar Creek. Washing down spilled water-compatible chemicals, such as gasoline and solvents, with fire hoses was a common practice. The contaminated water was allowed to drain via the storm water system to either Poplar Creek or Mitchell Branch. The storm water pathway is still an avenue for transporting contamination to nearby creeks. For example, PCB-contaminated oils likely migrated off site through such mechanisms as storm water runoff, discharges from onsite holding ponds, and flooding events at waste storage areas. In addition, hexavalent chromate usage in the cooling tower water treatment program has been verified as far back as 1956. It is estimated that K-25 discharged one million pounds of blowdown water a day, which was ultimately discharged to Poplar Creek after passing through a holding pond and a neutralization bed. The maximum chromium concentration of 0.05mg/L reported in Poplar Creek is one-half of the drinking water standard of 0.1 mg/L, but equal to the hexavalent chromium level regulated by the site's National Pollutant Discharge Elimination System (NPDES) permit.

The primary sources of radioactive liquid effluent at ORGDP have been the uranium recovery and decontamination operations. The K-901A pond primarily received recirculating cooling water waste from the enrichment processes beginning in the late 1950s. It is estimated that from the mid-1960s until 1975, the residual contents of 200 to 530 UF_6 and other gas cylinders stored at K-1025 were emptied into the K-901A pond by shooting the partially submerged cylinders with high-powered rifles. The unlined K-1407B holding pond received radioactive and hazardous materials from 1943 to 1988. This pond discharged into Mitchell Branch and then to Poplar Creek. Uranium recovery processes such as those in K-1410, K-1420, and K-131 were the primary sources for radioactive liquid effluents. The K-1410 uranium cleaning and decontamination activities began in the late 1940s and continued until 1962. The K-1420 chemical operations facility began operation in the mid-1950s. These processes released residual concentrations of technetium-99, uranium, neptunium-237, and plutonium-239 to nearby streams. Building K-131 housed distillation equipment and used carbon tetrachloride in the recovery process. If economically feasible, decontamination and cleaning solutions from K-1410 were transported to K-131. If not, the solutions were discharged directly to Poplar Creek. K-1410 was modified for nickel plating operations in 1963, and an underground pipeline was installed that would discharge from the neutralization pit to Poplar Creek during overflow conditions. These operations ceased in 1979.

Discharges from the K-1420 operation went to the K-1407B pond. During early operations, spent degreasing solutions were discharged through a process drain line to this pond if they contained low concentrations of uranium. This pond was a receiving body for transuranics from the site. The K-1407C pond was built in 1973 for storing sludge that was being dredged from the K-1407B pond. Over 80,000 drums were generated when the K-1407B and C pond sludges were removed in 1988. In addition to the K-1407B and C ponds, the K-1064 (peninsula) scrap yard contributed most significantly to the releases of liquid containing technetium-99.

2.8 Management, Oversight, and Employee Relations

ES&H oversight by Federal agencies and the ORGDP contractors varied significantly in extent and rigor over the more than 50 years of operation. From the 1940s through the 1970s, ES&H oversight was minimal and did not aggressively address unsafe and unsound ES&H practices and performance. The succession of Federal organizations responsible for the ORGDP have had operational field offices in Oak Ridge and construction or site offices at the Plant site continuously. However, day-to-day oversight was primarily directed at ensuring that production objectives were achieved, with limited inspection and direction regarding ES&H performance. Until the late 1970s, field office ES&H activities consisted primarily of short, one- or two-person annual assessments of several functional area programs. These assessments were not always rigorous, and their limited scope included minimal direct observation of field conditions and performance. When a formal site office was established in the late 1980s, ES&H field performance reviews increased.

The Washington headquarters offices of the Federal agencies responsible for ORGDP set ES&H policy, established expectations and exposure limits, and aided in structuring programs to comply with evolving environmental, industrial hygiene, safety, and radiological regulations. Until 1947, the Army was involved in determining initial health and radiological safety limits and practices; it actively participated in site operations, especially the S-50 thermal diffusion process. However, after the AEC was formed in 1946, Federal agency headquarters oversight of ES&H at ORGDP was minimal until the late 1970s, when the DOE Office of Environment, Safety and Health started performing periodic ES&H assessments.

Before 1950, ES&H professionals were responsible for establishing hazard controls and monitoring conditions and performance. Starting in 1950, and for more than 20 years thereafter, it was Union Carbide policy that ES&H monitoring and personnel protection were line functions. As a result, the number, influence, and authority of the contractor's independent ES&H professionals were limited. Line supervisors were trained in ES&H and were expected to communicate information on hazards and controls to the workers. However, monitoring and ES&H performance declined. In the 1970s, the ES&H organizations assumed more responsibility for oversight and for worker compliance and performance.

Workers at the ORGDP have been represented by the Oil, Chemical, and Atomic Workers Union (OCAW) since September 1946 and by the United Plant Guard Workers of America (UPGWA) since January 1949. Approximately 10,000 union grievances were filed between 1946 and 1997, with no clear pattern related to the identification and resolution of ES&H matters. The EH investigation team identified examples of worker grievances protesting safety requirements and training and examples of management disputing grievances concerning safety-related issues in favor of economic considerations. Plant workers were involved in three strikes: in 1954 for three days, in 1961 for 16 days, and in 1975 for 28 days–all related to wages. Interviews with numerous former workers in a variety of positions at the ORGDP indicated a common perception that retribution, in the form of assignment to undesirable work tasks, often resulted from workers' raising safety and health concerns or questioning existing conditions or practices.

SIGNIFICANT MILESTONES AND EVENTS – 1943 TO 1996

January 1943	Carbide and Carbon Chemicals Corporation contracted to operate the K-25 Plant
April 1943	The “Clinton-TVA” site selected for K-25 Plant
September 1943	Construction of Building K-25 begins
January 1945	UF_6 fed to first cell in Building K-25
March 1945	First product withdrawal and shipment to the Y-12 Plant
May 1945	Union Carbide employment at K-25 peaks at 11,379
January 1946	Building K-27 begins full operation
December 1946	Weapons grade product first withdrawn at K-25
December 31, 1946	AEC succeeds Manhattan Engineer District (Army)
December 1947	Barrier production begins at K-25 in K-1037
September 1950	Building K-29 begins operation
November 1950	Feed manufacturing plant in K-1131 goes into operation
January 1951	Building K-29 completed and begins full operation
August 1951	Building K-31 begins initial operation
December 1951	Building K-31 completed and begins full operation
July 1954	OCAW strike
November 1954	Building K-33 completed and begins full operation
1955	Site name changed to the Oak Ridge Gaseous Diffusion Plant
November 1960	AEC authorizes gas centrifuge process experimental work
October 1961	Feed manufacturing plant ceases operation
October 1961	OCAW strike
November 1961	12 gas centrifuge machines in operation in K-1004J
November 1961	Nickel carbonyl release in K-1004D; six employees exposed
July 1962	K-27 fatality and five injuries from circuit breaker explosion
1964	Enrichment for weapons production ceases
August 1964	Buildings K-25 and K-27 are placed in standby (except for purge cascade)
1969	Toll enrichment program begins
1971 – 1981	ORGDP CIP/CUP conducted
August 1974	UF_6 release exposes 28 employees – 11 over the exposure limit
1975	Centrifuge Test Facility begins operation in K-1210
January 1975	ERDA assumes regulatory responsibility for ORGDP from AEC
October 1975	OCAW strike
July 1976	Buildings K-25 and K-27 are permanently shut down (except for purge cascade)
1977	Sections K-402-9 and K-402-8 of Building K-27 are reactivated
October 1977	DOE assumes regulatory responsibility from ERDA
1982	Barrier plant closes
1983	OSHA Hazard Communication Standard is issued
April 1984	Martin Marietta assumes operational responsibilities from Carbide and Carbon Chemicals Corporation (now known as Union Carbide/Nuclear Division)
August 1985	Sections K-402-9 and K-402-8 of K-27, K-29, K-31, and K-33 all placed in standby
December 1987	Sections K-402-9 and K-402-8 of K-27, K-29, K-31, and K-33 permanently shut-down
1989	Oak Ridge Gaseous Diffusion Plant renamed the K-25 Site
December 1991	DOE Tiger Team Report issued
March 1995	Martin Marietta becomes Lockheed Martin following a merger
1996	The K-25 Site is renamed the East Tennessee Technology Park